

THE ANNALS
AND
MAGAZINE OF NATURAL HISTORY.

No. 79. DECEMBER 1843.

XLVI.—*General results of Microscopic Inquiries into the Minute Structure of the Skeletons of Mollusca, Crustacea and Echinodermata.* By WILLIAM B. CARPENTER, M.D.*

[With two Plates.]

HAVING been engaged, during the last eighteen months, in microscopic researches into the skeletons or hard parts of animals, and having had my attention particularly directed towards the shells of Mollusca and Crustacea, and to the shells, spines, stems, &c. of the Echinodermata, I have been led to believe that a short *résumé* of the results at which I have arrived, would be interesting to the members of the Geological Section of the British Association, and might prove of importance in giving a stimulus to further inquiry. Were it not, indeed, in the hope that the advance of science might be promoted by my bringing forward these results in their present form, I should have hesitated in doing so, until they had attained more completeness. I shall commence with the Mollusca, as presenting the greatest number of points of interest.

Mollusca.

The first point on which I desire to lay stress, is the complete distinctness of the organic basis of the shells of Mollusca from the calcareous portion. The two are not uniformly diffused through the shell, as some have supposed, but are separate elements, each having its own place. The organic or animal basis presents very definite characters, by which its nature may be determined, when the calcareous portion has been removed by the action of an acid.

I also think it desirable to state, *in limine*, that the structure of all shells appears to me to be equally *crystalline*; the carbonate of lime uniformly presenting a crystalline *arrangement*, if not a regular form. I cannot admit, therefore, the distinction between the *crystalline* and *concretionary* shells which Mr. Gray has attempted to establish; nor can I recognise the two forms of cry-

* Read to the Geological Section of the British Association, August 1843; and communicated by the Author.

stallization, the *rhomboidal* and *prismatic*, as characterizing different groups, for reasons which will appear in the course of this paper. The *crystalline aggregation* of the particles of calcareous matter in shell appears to me to be proved by the transparency of thin sections (except where patches of uncrystallized or chalky matter sometimes present themselves), and by their effects upon polarized light. It is very evident in some few instances, in which a distinct crystalline *form* is presented. One of the most remarkable of these is the tooth of *Mya arenaria*, a section of which presents the remarkable appearance shown in fig. 8 (Plate XIV.), bearing a strong resemblance to that of Wavellite or radiating Arragonite. I have found distinct rhomboidal crystals in certain imperfectly calcified layers, which occasionally present themselves in *Ostrea edulis*; and similar crystalline deposits have been described as existing in the dense integument of some Ascidians.

The first distinction established by the microscope, between the different forms of shell-structure, has reference to the nature of their organic basis. This, in most shells, consists but of a simple *membrane*, of extreme tenuity, and not presenting the slightest trace of *structure*, even when examined under the highest magnifying powers. This membrane is obviously analogous to the *basement membrane* lately described by Mr. Bowman ('Cyclopædia of Anatomy and Physiology,' art. *Mucous Membrane*) as existing between what is commonly termed the *true skin* and the overlying *epidermis*, and also between the ordinary mucous membrane and its epithelium; and I am inclined to believe that it originally holds the same position on the mantle of the mollusk, and that it is cast off with each new layer of shell. We shall presently have to notice the remarkable variations, in the microscopic appearance of sections of shell, which are produced by the differences in the manner in which this membrane is arranged. It may be easily obtained by submitting the *internal* layer of any shell (whether nacreous or not) to the action of dilute muriatic acid, until all the calcareous matter has been removed. In the porcellanous shells it is so extremely delicate, that, when thus separated, it is liable to be overlooked; and it seems to be dissolved by the acid, if left in it for too long a time, or if the acid be too strong.

In certain bivalve shells, however, an entirely different kind of membranous basis remains behind, after the calcareous matter has been removed by acid. This consists of a stratum of *prismatic cells*, adherent together at their sides, and forming by their extremities the two surfaces of the membrane, which thus presents the appearance of a honey-comb. This is most characteristically seen in *Pinna*; nearly the whole of which shell is formed of this *prismatic cellular* substance, as may be easily shown by examining

the thin laminæ into which it separates, without any preparation, by the aid of even an ordinary microscope. These cells are usually hexagonal in form, but are not very regularly so. Their size varies considerably, both as to diameter and length, even in the same shell. When very long, the layer which they form will possess considerable thickness; when they are very short, it will be delicately thin. The cells are usually the longest in the outer layers. I have seen a recent *Pinna* in which one of these was nearly $\frac{1}{6}$ th of an inch in thickness; and I have seen this far surpassed in fossil shells allied to this genus, as *Inoceramus*, *Pachymya*, &c.; yet in the very same shells, the inner layers were thinner than a sheet of writing-paper. Although there are considerable variations in the diameter of the cells, in different parts of the same individual, and still more in different species of the same genus, yet there appear to be certain limits; so that some shells may be characterized by the coarseness of their prismatic structure, and others by its fineness. The *coarsest* I have yet met with is in *Inoceramus*, the *finest* in *Pandora*; and the difference is so great, that at least 250 cells of the latter would be covered by one cell of the former (Plate XIII. figs. 1 and 2).

The resemblance, in their structure and position, between the prismatic cellular substance of shells, and the prismatic epithelium covering the mucous membranes of higher animals, leaves no room for doubt of their analogy; and we may consider this form of shell-structure in the light of a *calcified epithelium*, the carbonate of lime being deposited in the cavities of the cells, and in general completely filling them. In most sections of *Pinna* a greater or less number of *dark* cells may be seen, which are usually disposed with some degree of regularity. These I have reason to believe to be cells incompletely filled with carbonate of lime; the spaces remaining in which, being occupied by air only, present a dark appearance under the microscope, according to the general principle well known to observers.

I think it cannot admit of a doubt, that the prismatic arrangement of the carbonate of lime in these shells is due to the nature of the organic basis in which it is deposited, and not to anything peculiar in its mode of crystallization. An interesting specimen of *Pinna* has lately been brought under my notice by Mr. S. Stutchbury, in which the thick outer layer had become disintegrated, during the life of the animal, by the decay of its organic structure; and the prisms of carbonate of lime were left *in situ*, but not in any way held together, so that they could be separated by a touch. On treating these prisms with dilute acid, I find them encircled by an extremely delicate membranous film; the remainder of the cells, in which they were originally formed, having been removed by decay.

It is not difficult for a person who has once become familiar with the appearance of this structure, to recognise it by the naked eye, when it presents itself in any considerable amount. It is known by its brownish-yellow colour, its elasticity (which is greater, and its brittleness less, than that of other kinds of shell-structure), and its prismatic or fibrous fracture. I have determined its existence, by thin sections examined with the microscope, in the following recent genera: *Pinna*, *Avicula* (*Meleagrina*), *Perna*, *Malleus* and *Crenatula*, belonging to the family *Margaritaceæ*; *Ostrea* and *Etheria*, which seem to be nearly related, if not to be included in the same family *Ostraceæ*; *Unio* and *Anodon*, belonging to the *Nayadeæ*; and *Pandora*. This last genus is the only exception I have met with to the general rule,—that the prismatic cellular structure is restricted to the group, of which the *Margaritaceæ* may be taken as the type or centre, the lobes of the mantle being almost or completely open and the foot small; and *Pandora* is altogether so anomalous a genus, that the systematist is greatly perplexed by it on other grounds than this.

The position of *Pinna* among the *Margaritaceæ* (of which it may be considered an aberrant form leading to the *Mytilaceæ*), the alliance of *Etheria* to this group rather than to the *Chamaeæ*, and the separation of the true *Ostraceæ* from the *Pectinidæ* on the one hand and from the *Placunidæ* on the other, which had been proposed by systematists on the ground of general characters, appear to me fully borne out, and indeed absolutely required, by the characters afforded by the structure of the shell.

I have examined several fossil shells which exhibit similar characters; such as fossil *Pinnae*, *Inoceramus*, *Pachymya* and *Gerwillia*, belonging to the *Margaritaceæ*; *Gryphæa* to the *Ostraceæ*; as well as *Unios*, &c. The prismatic cellular structure is extremely well preserved in nearly all fossil shells; and is very easily recognised, either by fracturing the shell or by making a thin section of it. The latter is necessary where it forms but a thin layer, as in *Gryphæa*, *Unio*, &c.; the former is sufficient where the layer is thick enough to give the fibrous aspect on fracture.

The determination which the use of the microscope thus enables us to make, of the family to which shells must be referred whose position would be otherwise doubtful, must be, I imagine, of very great use to the geologist, even were that use limited to the few families I have yet named, which is by no means the case. The following will serve as a good example. A certain shell from the lias has been described and figured by Prof. Phillips under the name of *Avicula cygnipes*; and the same or a closely allied species by Mr. S. Stutchbury, under the name of *Avicula longicostata*. These gentlemen were not unaware of its affinity to the *Pectinidæ*, but thought that the characters of *Avicula* predomi-

nated. On examining a portion of it, however, which Mr. Stutchbury submitted to me, I was able most decidedly to assert, that it possessed the intimate structure of the shell of the *Pectinidæ*, whilst the prismatic cellular structure and nacreous lining of *Avicula* were altogether wanting.

The prismatic cellular structure always occupies the *exterior* of the shells in which it occurs; and their inner surface, as well as the whole thickness of a large number of shells, is formed of *membranous* shell-structure, by which I designate that structure which seems to consist of alternating layers of carbonate of lime and of the very delicate membrane already described. This membrane is seldom or never *flat*, however, but is folded into plications like those of a frill, or corrugated into wrinkles like those on morocco leather, or arranged in other ways which cannot at present be fully described, but which are characteristic of particular families. These modes of arrangement determine the mode in which the carbonate of lime is deposited, so that they become perfectly evident when a thin section of a membranous shell is examined with a microscope; and they also determine the appearance produced on fracture. Thus Mr. Gray has pointed out the alternating directions of the rhomboidal crystals seen on fracturing a porcellanous shell, such as *Conus* or *Cypræa*; and these I believe to be entirely due to the alternating directions of the membranous corrugations, which are shown by a section. In like manner, the prismatic fibrous appearance, which is presented by *Mytilus*, and by *Septaria* (*Teredo*) *gigantea*, on fracture, is due to the peculiarity in the form and direction of the plications of the membranous basis; and the microscopic appearance of the latter corresponds so precisely with that, which is to be seen in well-preserved specimens of the fibro-calcareous sheath of the *Belemnite*, that I cannot but regard the structure of this interesting fossil as completely analogous to that presented by the thick tube of the recent *Septaria*.

There are two varieties of the membranous shell-structure, which are produced by marked peculiarities in the arrangement of its organic base; and which are so easily recognised by the microscope, as to become of great use in determining the characters of fossil shells. The first of these exists in *nacre*. That the nacreous lustre is due to lines or striæ, occurring within certain distances from each other, was long ago shown by Sir D. Brewster; but my inquiries into the constitution of nacre have led me to a view of their cause somewhat different from his. Instead of regarding them as produced by the alternation of numerous layers of membrane and calcareous matter, I have ascertained that they are due to the plication or folding of a single layer, in such a mode that the folds shall lie over one another in an imbricated

manner (fig. 3). The edge of each fold therefore marks a line; and the distance of the lines from each other will greatly depend upon whether the cutting-plane coincides with the plane of the folds, or is more or less inclined to them. As the curvature of the layers of shell causes the cutting-plane to traverse them differently in different parts, a single slice of nacre will often show great varieties in the disposition of the lines; just as the same deal board shows the woody layers very differently divided in its different portions.

The view I have given of the structure of nacre is fully proved, I conceive, by the following fact. It is occasionally possible to obtain a single layer of nacre, the *membrane* of which, after the complete removal of the calcareous matter by acid, exhibits the true nacreous lustre, so long as the arrangement of its folds remains undisturbed; but as soon as the membrane is extended, so as to obliterate the folds, the nacreous lustre departs.

I have found approaches to the nacreous structure in many shells, in which the folds are not sufficiently regular for the characteristic lustre to be exhibited. It is easy to understand, therefore, why there should be a variation in this respect, within the limits of a single genus. Thus in *Ostrea* there is usually no perfect nacre, yet there are species which are truly nacreous. On the other hand, in *Mytilus* there is usually a truly nacreous interior, yet there are species in which this is wanting. When so very slight a difference in the arrangement of the folds will produce this variation, it is not surprising that it should occur among the species of the same genus.

The nacreous and even the subnacreous structure may be easily recognised by the microscope, wherever they occur, both in the recent and fossil state. It sometimes requires a microscope of very good defining power, however, to separate the lines. As it frequently happens that a nacreous *structure* is thus shown to exist in fossil shells, where, from some peculiarity in the fossilization, the characteristic *lustre* does not present itself, I should imagine that this microscopic character must frequently be of great importance to the geologist. The absence of any vestige of it was one of the grounds on which I felt justified in determining that the so-called *Avicula*, just now mentioned, could not belong to that genus.

The other peculiar form of plicated membranous structure is that which presents itself in *Terebratula* and other allied genera of the group of Brachiopoda. It is difficult to give, in words, a description of this peculiarity, but it will be at once understood by reference to figs. 6 and 7, Plate XIV.; and, when once seen, is always recognisable with facility. The best mode of showing this peculiar structure I have found to be, the detaching very thin

shreds with the point of a pen-knife ; this is very easily accomplished in many fossil species, especially those deeply plicated ones which are usually ranked among the *Terebratulæ*, and best, among recent species, in the *Terebratula psittacea*. It is by the appearances exhibited by these *natural laminae* (fig. 7), that those presented by artificial sections (fig. 6) must be interpreted. This kind of structure is to be seen in *Terebratula*, *Spirifer* and *Pentamerus*. In *Producta* there is a difference in the mode of plication, which takes on the *nacreous* character ; and it is interesting to remark, that whilst, in the structure of this shell, there is an approach towards the Lamellibranchiata, there is, among the *Placunidæ* (which probably, of all Lamellibranchiata, approach nearest to the Brachiopods), a manifest tendency, in the peculiar lamination of the shell and in the arrangement of the nacreous plications, to the characteristic structure of *Terebratula*, &c.

One of the most interesting points in the structure of *Terebratula*, or, at least, in certain species of it, is the existence of a large number of tubular perforations, passing directly from one surface of the shell to the other, and terminating by an orifice at each (fig. 6). The size of these perforations is sufficiently great to enable them to be detected with a hand magnifier, as minute punctations on the surface ; and in this manner I have observed them in all the recent species of *Terebratula* (about fourteen) which have come under my notice, except in the *Ter. psittacea*, which departs so widely from the general type, in the incompleteness of the passage for the ligament, that (as Mr. S. Stutchbury has suggested to me) it is probably to be considered as the recent type of *Spirifer* *. Of the very numerous fossil species of *Terebratula*, I have yet examined but a small proportion : yet the curious result has uniformly presented itself, that the perforations have invariably been found in the non-plicated or moderately plicated species ; whilst they have been absent in those which differ from the recent species, in being much more deeply plicated. Now the structure of the shell in the genus *Spirifer* agrees with that of *Terebratula* in every respect, save the absence of these perforations † ; I should therefore be inclined, from this character alone, to place *Ter. psittacea* in the genus *Spirifer*, and to refer to the same group those deeply-plicated species, which are usually ranked with *Terebratula*. Whether this be thought a correct

* I have since learned that this species has been separated, and made the type of a new genus, *Atrypa*.

† This statement applies only to the Spirifers of the carboniferous limestone ; for in the *Spirifer Walcotii* of the lias, which I have recently examined, the perforations are present, as in the true *Terebratulæ*. The whole subject will require very careful investigation before any legitimate conclusions can be drawn from this kind of examination, in a group of the value of whose several characters we at present know so little.

determination or not, I think no doubt can be entertained, that the presence or absence of these perforations affords a most important character, by which the genus *Terebratula* may be divided. I should mention, that the determination of this character cannot be certainly effected, in fossil species, without making a section of the shell; since the perforations are often filled up with stony matter, in such a way as to obliterate the punctations on the surface.

The diameter of these perforations in *Terebratula* is usually about $\cdot 0006$ or $\cdot 0008$ of an inch. In *Producta* they are larger, being about $\cdot 0010$ or $\cdot 0012$ of an inch; and they are readily discernible with the naked eye in thin sections or in fractured pieces of the latter. They are readily distinguishable in the decalcified membranous basis of the recent species, and are obviously lined by distinct membranous tubes. I am much inclined to believe that these tubes are prolongations of the mantle, which Mr. Owen has observed to possess an unusual adhesion to the shell.

I cannot but think that the value of the microscope, as an instrument of geological research, must be at once evident from these statements. The genera *Terebratula*, *Spirifer* and *Producta** may be at once distinguished from each other, and from all other shells, by the characters supplied by a fragment of shell, which a pin's head would cover.

Whilst upon the structure of the Brachiopoda, I may mention (though rather anticipating my next head), that the genera *Lingula* and *Discina* (*Orbicula*) agree with each other, and differ entirely from the rest, in a very peculiar set of characters:—their shells possess extremely little calcareous matter, being made up of thin horny plates adherent to each other; every one of these horny plates, however, is traversed by a set of very minute tubuli running aslant through it, and very closely resembling, both in size and arrangement, the tubuli of *dentine*, and those which I have observed in the shell of Crustacea. I have nowhere else discovered, among Mollusca, a structure which could be mistaken for this. Consequently these two genera are at once separated, by microscopic examination, from all others.

The *tubular* variety of membranous shell-structure, as it exists in the shells of certain Lamellibranchiata and Gasteropoda, is the last form which I have at present to describe. The size of these tubuli varies from about $1\text{-}20,000\text{th}$ to $1\text{-}3500\text{th}$ of an inch; but their general diameter, in the shells in which they most abound, is about $1\text{-}6000\text{th}$ of an inch. The direction and distribution of these tubes are extremely various in different shells. In general they form a network which spreads itself out in each layer, nearly

* If I am correct in the characters I have assigned to them.

parallel to its surface; from this network branches seem to pass both upwards and downwards, as if to communicate with corresponding reticulations in other layers. The most characteristic example of this kind which I have met with, is in the genus *Lima*, of which the whole shell is minutely traversed by these reticulated tubes (fig. 5). In most families whose shells are entirely *membranous* (that is, destitute of the prismatic *cellular* structure), I find the tubular structure present in some genera and absent in others; so that I am inclined to think that it may serve as an important aid, in separating genera which are otherwise closely allied.

The tubular structure is often well preserved in fossil shells, and is distinctly seen in the *Avicula longicostata* already referred to. As this example is one of peculiar interest, in regard to the value of the microscope in determining the nature of fossil shells, I subjoin a summary of the characters by which I judge it to be *not an Avicula*, but nearly allied to *Lima* or *Plagiostoma*.

<i>Avicula, and other Margaritaceæ.</i>	<i>Avicula (?) longicostata.</i>		<i>Lima, Plagiostoma, and allied Pectinidæ.</i>
<i>External layer.</i>	<i>External layer.</i>	<i>External layer.</i>	<i>External layer.</i>
Prismatic cellular structure.	No cellular structure.	Coarsely plicated membranous structure.	Coarsely plicated membranous structure.
<i>Internal layer.</i>	<i>Internal layer.</i>	<i>Internal layer.</i>	<i>Internal layer.</i>
Nacreous.	Not nacreous.	Tubular structure.	Tubular structure.

It is worth notice, that in the genus *Pecten* there is not the slightest trace of the tubular structure, whilst the shell of *Lima* is more completely tubular than any I have examined. Hence we might consider the difference between them to be more than *generic*; a conclusion which harmonizes exactly with that of M. Deshayes, founded upon the structure and habits of the animals by which these shells are respectively formed.

The foregoing may be regarded as *specimens* of the important results which I think may be anticipated, from the application of the microscope to the structure of shells. When once marked differences in the arrangement of the organic elements of shell are shown to exist, the question naturally arises, how far these may be adopted as characters in classification; and I think it will be evident, from the facts I have stated, that this may be done to a very considerable extent. There are several families among which I have not yet discovered well-marked points of difference, especially in Univalve shells, and in Lamellibranchiata with the lobes of the mantle united; but I have little doubt that such characters may be ascertained, by a more extended inquiry than I have yet had the opportunity of making. Except in the case

of *Pandora*, to which I have already adverted, I have not met with a single exception to the rule,—that marked differences in the structure of shell go along with marked differences in general characters, and that a close correspondence in the structure of the shell may be held to indicate a tolerably close natural affinity. Many circumstances which at first appeared to me *exceptional*, were explained in the course of my investigations, by my finding (chiefly from the *notes* of M. Deshayes to the new edition of Lamarck) that the views of systematists had recently undergone modification, on several points, from increased knowledge of the structure of the animals, *so as, in fact, to become precisely accordant with the inferences which I should have been disposed to draw from the structure of the shell alone.*

In concluding this part of my subject, it may be interesting to my geological auditors, if I say something in regard to the effects of *fossilization* under different circumstances, on the structure of shell. The fossil shells I have examined have been chiefly from the carboniferous or mountain-limestone, *lias*, and oolite. Those from the carboniferous limestone are frequently changed by a process of crystallization, to such a degree that no organic structure is discernible in them; but the characteristic structure of the Brachiopoda is usually well preserved. The *membranous* shells of the *lias* are usually well adapted for microscopic inquiry; but they split with unusual facility into layers, as if they had undergone very prolonged maceration. The *cellular* shells, from the same cause, are disposed to disintegrate into their component prisms, so that it is difficult to prepare them for the microscope. On the other hand, the *membranous* shells of the oolite are apt to be entirely changed by crystallization, so that not a trace of the organic structure is preserved; whilst the structure of the *cellular* shells is remarkably perfect, and even the membrane which separates the prisms is in some instances preserved. I have not found shells from the *chalk* good subjects for microscopic examination: their texture seems to be permeated by chalky particles, which give it a peculiar opacity, resembling that which is seen, from the same cause (occurring in the natural formation of the shell), in *Ostrea*, *Fusus despectus*, and other shells distinguished by their opake-white aspect.

Crustacea.

In regard to the microscopic structure of the hard envelopes of Crustacea, I can as yet only speak from examination of the common Crab and Lobster; but the facts which this examination has disclosed are so curious, as to render it desirable to state them in this communication.

The envelope of the crab and lobster consists of three layers:

internally a thick calcareous layer, the surface of which is raised up in little papillary elevations; upon this lies a layer of *pigment-cells*, to which the colour is due; and externally is a structureless horny epidermis. The pigment-cells fill up the valleys or intervals between the papillary elevations of the calcareous layer, but do not cover the latter; the epidermis, which is quite smooth, lies flat upon the whole, adhering to the tops of the papillæ; so that, when the shell is closely examined from the outside, it is seen to have a minutely-speckled appearance, the red ground given by the pigment-cells being studded with the white tops of the papillæ which rise up through it.

The calcareous layer is composed of a substance exactly analogous to ivory, being very transparent and apparently homogeneous, when cut into very thin slices, and being perforated by an immense number of minute sinuous tubuli, which run nearly parallel to one another from one surface of the shell to the other. This arrangement may be seen by making a thin section of any part of the shell; but it may be shown particularly well in the end of the claw, which is thicker and of denser texture than the rest. A transverse section of this shows the tubes radiating from the central cavity towards the external surface, and would, I feel assured, be regarded by the most experienced observer as the section of a tooth, if he were not informed of its real nature.

Echinodermata.

The microscopic structure of the shell of *Echinus* has been very completely analysed by Valentin, in his monograph of the anatomy of that genus, published last year in the beautiful work of M. Agassiz on this group. Before becoming acquainted with his researches, I had arrived at conclusions exactly identical, and had extended my inquiries to all the other most important genera of the *Echinida*, *Stellerida* and *Crinoidea*. The result has been extremely interesting. Every part of the skeleton in these groups is made up of a structure so uniform, and at the same time so unlike everything else, as to be most characteristic of the group; so that there could be no hesitation, wherever the merest fragment of this structure might be distinguishable, in pronouncing it to have belonged to an Echinoderm. I have reason to believe that minute calcareous plates, having an identical structure, occur beneath the integument of some *Holothurida*; if this be the case (which, for want of a specimen, I have not yet had the opportunity of ascertaining), the universality of the character, as distinguishing the whole group of *Echinodermata*, will be completely established.

The structure to which I allude consists of a series of very thin plates, each perforated by a number of round apertures,

disposed with tolerable regularity, so as to give it the appearance of a *cullender*. These plates are connected with each other by little vertical pillars, which pass from surface to surface in vast numbers: hence, when a section is made perpendicularly to the surface of the plates, a kind of network is seen, formed by the cut edges of the plates and by the pillars. In the *shells* of *Echinus*, *Cidaris*, *Spatangus*, &c. these plates run nearly parallel to the surface, and are of course nearly plane; whilst the pillars are perpendicular to these, so that the interstices of the network are nearly square: but in the *spines* of *Cidaris*, *Echinus*, &c. the plates are disposed in a cylindrical manner round the central axis, and the network which is displayed by a transverse section is arranged in concentric rings. The *pattern* of this network in many spines is of the most wonderful beauty and elaborateness; and, as far as I have yet examined, it is so regular in the same species and so different in others, that I am inclined to believe that it will become most valuable in the distinction of species.

A similar cylindrical arrangement, producing the same effect, is seen in the stem and arms of the recent *Pentacrinus*, thin sections of which are extremely beautiful objects for the microscope.

Contrary to the expectation of some of my mineralogical friends, I have been able to discover the same structure in fossil specimens, in which the crystallization was so complete, that they could not be cut without great difficulty, on account of their tendency to cleavage. This has been the case with the *Crinoidea* in general; a definite structure being presented by nearly all the specimens that I have yet examined, though it has been more evident in some than in others. The structure of the round-stemmed species is usually very simple; a transverse section exhibiting several concentric rings or layers, like those of exogenous wood, with no variety in the pattern of the reticulation. But in the *Pentacrinites Briareus* the structure is extremely complex. From the centre there proceed five medullary rays (if so they might be designated), from the edges of each of which are given off numerous side-branches; and the reticulations of the central portion and its prolongations are very distinct from those of the periphery. Now in the recent *Pentacrinus Caput Medusæ* the pattern is simpler; for though the medullary rays exist, they do not send out lateral branches, and their structure is not so different from that of the portion that surrounds them. In a fossil species, supposed by Mr. Miller to be identical with the recent one, I have found the structure of the stem to be intermediate between that of the *Pent. Briareus* and that of the *Pent. Caput Medusæ*; the medullary rays sending out *short* prolongations, which soon lose themselves in the surrounding structure. I cannot but suppose, therefore, that analogous differences might

be found among other species of *Pentacrinus*, and that indubitable specific characters (which are much wanted in this genus) might be established upon these.

In conclusion, I desire to make it known, among those who may feel an interest in this inquiry and who may perceive its importance, that I shall feel particularly obliged by being supplied with specimens for examination; that by extending the basis of my inquiries, my general conclusions may acquire a value and stability, which I am conscious that they do not at present possess. Single or imperfect valves of any of the rarer recent genera, and fragments of almost any fossils in which the shelly structure is well preserved, will be gratefully received by me; and I shall do my best to make them available for the purposes of science.

ADDENDUM.

Having been encouraged by the British Association to carry out these investigations, and having been requested to furnish a detailed Report on the Microscopic Structure of Shells, &c. for its next meeting, I am particularly anxious to lose no time in examining as large a number of species, both recent and fossil, as I may be enabled to do, by the kind assistance of those who may be disposed to promote my object. Any contributions of the kind specified above may be forwarded to me direct through the post-office if not too bulky; and Mr. Lovell Reeve, King William Street, Strand, and Mr. Woodward, Geological Society, have kindly undertaken to assist me, by receiving and forwarding to me any specimens that may be transmitted to them.

I may subjoin, as interesting results of observations made since the meeting of the Association, the identification of the remarkable structure of *Pleurorhynchus Hibernicus* (*Cardium Hibernicum*) with that of *Hippurites* and other *Rudistes*; leaving no doubt in my own mind of their close affinity, this structure being, so far as I know at present, peculiar to the last-named group. It has given me great pleasure to learn, that several intelligent conchologists had formed the same opinion on independent grounds; though, so far as I am aware, it has never been put forward in print, and I was entirely ignorant of it at the time my own observations were made. The structure in question is of a *cancellated* nature, filling up the space between the internal and external layers of shell, in the same manner as the *diploe* fills up the space between the two tables of the skull. The *cancelli* are very regular in form and arrangement; and though they are now filled with carbonate of lime, I think its appearance indicates that it is the result of fossilization. I am not acquainted with cancellated structure exactly resembling this in any recent shell; the nearest approach to it is presented by *Balanus*, *Coro-*

nula, and other sessile Cirrhipods; and I am much inclined to believe that the real place of this perplexing group will prove to be intermediate between the Conchifera and the Cirrhipoda—an idea which has derived confirmation from the examination of the very beautiful series of specimens in the collection of S. P. Pratt, Esq., which it is to be hoped that he will take an opportunity ere long of communicating to the public.

I may state that the specimens most acceptable to me at present are those of the various genera of Brachiopoda; as I am very desirous of fully investigating this group before making my first Report. But I shall be very glad to receive *any* others, provided that the name of the shell is specified, when a fragment only is sent; and the bed from which it is obtained, if it be a fossil.

W. B. C.

Bristol, Nov. 16, 1843.

EXPLANATION OF PLATES XIII. XIV.

- Fig. 1.* Appearance of the membrane of a thin layer of the outer part of the shell of *Pinna*, taken parallel to the surface, after removal of the calcareous matter by acid.
- Fig. 2.* Thin section of the outer part of the shell of *Pinna*, not acted on by acid; two small black cells are seen, in which the calcareous matter is deficient.
- Fig. 3.* Section of Nacre, showing the wavy, but usually parallel lines, produced by the plaiting of the basement membrane.
- Fig. 4.* Section of *Avicula* (?) *longicostata*, showing its coarsely corrugated structure penetrated by tubes.
- Fig. 5.* Section of the inner part of the shell of *Lima rudis*, showing a finely corrugated structure abundantly traversed by tubes.
- Fig. 6.* Section of *Terebratula* (recent), showing its peculiar structure, and the large perforations by which the shell is traversed at right angles to the surface.
- Fig. 7.* Shred of *Terebratula* (fossil) detached by the point of a knife, from a deeply-plicated specimen; the difference of aspect between this specimen and the last is entirely due (except in regard to the perforations) to the mode in which the section is made; a natural lamina being obtained in the one case, whilst in the other the plane of section traverses the natural laminæ obliquely.
- Fig. 8.* Section of the tooth of *Mya arenaria*, showing a remarkable crystalline arrangement.

XLVII.—*Description of some New Species of the Genus Pachyodon.* By Capt. THOMAS BROWN, M.W.S., M.R.P.S., Curator of the Manchester Natural History Society's Museum, &c.

[With three Plates.]

1. *Pachyodon Gerardi.* Pl. XV. figs. 1, 2.

TRANSVERSELY ovate, inflated, thickness equal to half its breadth; umbones produced, rounded, and contiguous; posterior side short and obliquely truncated; anterior side long and subtrun-